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COHERENT ATOMIC DEFLECTION BY RESONANT PLANE WAVES*

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Abstract

We show examples of coherent motion of two level atoms in oppositely directed, near resonant, monochromatic plane waves as a function of frequency detuning and initial direction of atomic motion.

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SUMMARY

We consider two-level atoms under the influence of near resonant traveling-wave fields. Quantization of both fields as well as kinetic and internal motions of the atom provides new insight into the mechanism responsible for deflection: atomic absorption and emission coherently transfer photons from one traveling wave to its counter propagating companion, thereby altering atomic momentum. The equations of motion turn out to be identical with equations which one obtains for a sequentially linked multilevel system with monochromatic electric fields in the rotating wave approximation -- the so-called N level atom[1].

Previous work[2,3] has shown that the RMS atomic momentum in a resonant standing wave increases in both directions normal to planes of constant phase by $\hbar\omega/c$ for each Rabi period $1/\Omega$ so long as there is no initial component of momentum normal to the wave fronts ($p_0=0$) and provided the accumulated transverse kinetic energy remained small compared to $\hbar\Omega$.

Our present work extends previous treatments to include off-resonance detuning and atomic beams which are not parallel to plane wave fronts. Our results, though limited to times shorter than relaxation times, extend the time scale of previous results significantly.

For the case of no detuning and $p_0 = 0$ we find the acquired maximum transverse momentum to be $p_{max} = \sqrt{2M\hbar\Omega}$. The time development of the distribution of transverse atomic momentum, p, is shown in the computer generated relief view of Figure 1. $P_n(t)$ is the probability of acquiring n units of transverse momentum, so that $p = n\hbar\omega/c$ (here n may be positive or negative; n = 0 initially). Note that linear growth in n ceases on reaching the turning point level $n_{max} = 5$. At all later times the probability remains within a band $n < n_{max}$.

For $0 < p_0 < p_{max}$ and short interaction times, the distribution is symmetric about the incident atomic direction. The turning points, however, are no longer symmetric about that direction and the maximum deflection is larger than when $p_0 = 0$. For sufficiently long times, the time averaged population distribution peaks at both P_0 and $- P_0$. The peaking becomes more pronounced as P_0 approaches P_{max}.

Finally, when $p_0 = p_{max}$, the distribution remains sharply peaked about P_0. After sufficient time, however, the population can "tunnel" through the forbidden region, appearing in a sharp peak about $p = - p_0$. This population oscillation is an illustration of what for the N-level atom would be termed a multiphoton resonance. The condition for this resonance is the Bragg condition for waves of wavelength equal to the atomic de Broglie wavelength scattering from a "lattice" of periodicity equal to the optical wavelength.

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Frequency detuning makes only slight alterations of the dynamics so long as the detuning is much smaller than the Rabi frequency. For larger detunings dramatic changes can occur: the maximum deflection increases and the Bragg scattering occurs on much shorter time scale.

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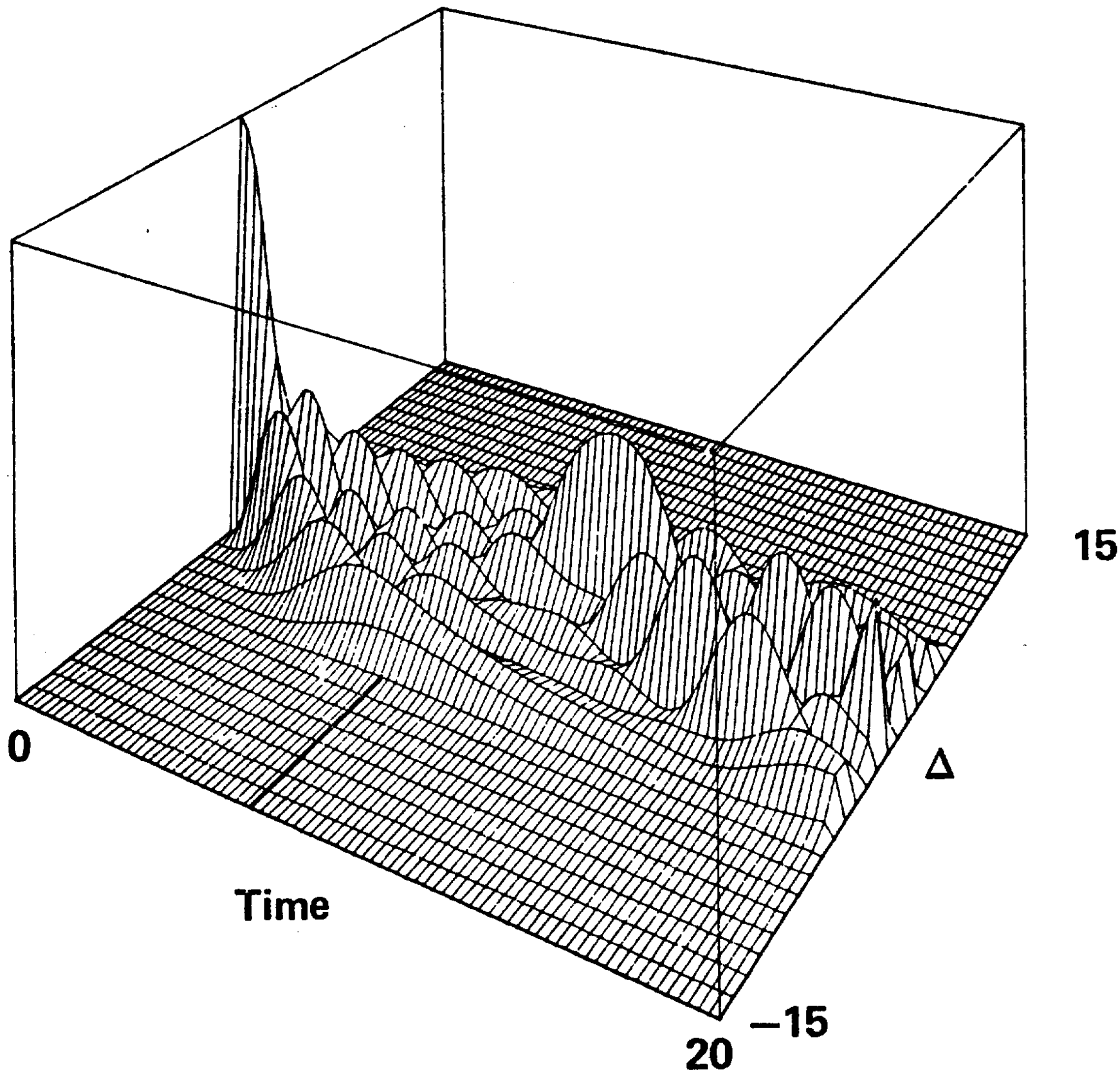

Figure 1.